COMPLEX CRATERS: RELATIONSHIP OF INNER RINGS TO THE IMPACTOR AND TRANSIENT CRATER EVOLUTION John D. O'Keefe and Thomas J. Ahrens, Lindhurst Laboratory of Experimental Geophysics, Seismological Laboratory 252-21, California Institute of Technology, Pasadena, CA 91125.

The diameter of the inner ring in complex craters was found to correspond to the diameter of the transient cavity. Moreover, the inner ring that corresponds to the transient cavity diameter has a rotated(vertical) stratigraphy that differentiates it from the other crater features and is observable by drilling, seismic imaging and gravity mapping.

Our objective is to understand how the observable complex crater features[e.g. rings, and central peaks, pits and rings] relate to the impactor's parameters [e.g. radius(a), velocity(U) and density(ρ)] and the transient crater measures [e.g. depth of penetration(d_p) and diameter(D_p)]. Previous efforts to address this problem have ranged from 1) dynamic [1,2] to 2) quasi-static models[3,4]. None of these models give an quantitative unambiguous answer to the observables issue. To address this issue we numerically modeled the early stage shock driven flow fields to the late stage strength and gravity contrained motions[2]. We used two strength models so as to bound the responses expected from planets with deep regoliths to hard rock surfaces. These were a temperature dependent thermal-degradation strength model [2,5], and Mohr-Coulomb pressure and temperature-dependent strength model [5]. Also we modeled fracturing and comminution using the Johnson-Cook approach[6]. These strength models resulted in significant differences in the final crater depth, diameter and other features[2].

Examples of simple bowl shaped, incipient flat floored and complex crater calculations are shown in figures 1-3. A primary parameter that determines the crater morphology is the non-dimensional strength, $Y/\rho g d_p$, where Y is planetary strength, g is the planetary gravity and d_p is the depth of penetration under zero strength conditions[2]. When $Y/\rho g d_p >> 1$, the impact produces simple craters and when $Y/\rho g d_p << 1$,the impact produces centerline oscillations and complex craters.

The formation of a complex crater is shown in figure 3. The time is nondimensionalized by dividing by (a/U). We placed tracer particles at various postions to delineate the effect of the crater motions on the deformation of the planets stratigraphy. The crater at the time of maximum transient crater diameter is shown in figure 3a. This occurs just prior to the upward flow of the crater floor to form an oscillating centerline peak. This transient crater diameter is 16 units. In the figure 3b, the oscillating peak has formed and is at its first maximum height. The crater lip which was formed during the development of the transient crater, has an inverted stratigraphy away from the transient crater. In contrast, during the formation of the transient centerline peak, the stratigraphy is rotated 90 deg. within the transient cavity. The first peak collapses and forms a second transient crater cavity which is shallower than the first. The stratigraphy near the centerline maintains it's pre-impact ordering, whereas the stratigraphy the "vertical ring region" has an 90 deg. rotation. This ring forms because the material near the centerline is weaker than the material near the base of the transient peak. The material near the centerline is weaker because of greater shock heating, plastic work, fracture and comminution. The second transient cavity rebounds and produces a small narrow second centerline peak; this decays to give a central structure. In the case shown there is a small centerline peak and ring. This ring does not have a rotated stratigraphy in contrast to the "vertical ring". The first peak during collapse and the final crater are shown in expanded vertical scale in figures 3e and 3f. Scaling laws [2,7] have been developed for the "vertical ring" and its relationship to the impact parameters and other crater dimensions. Implications of these for Chicxilub and other craters are presented

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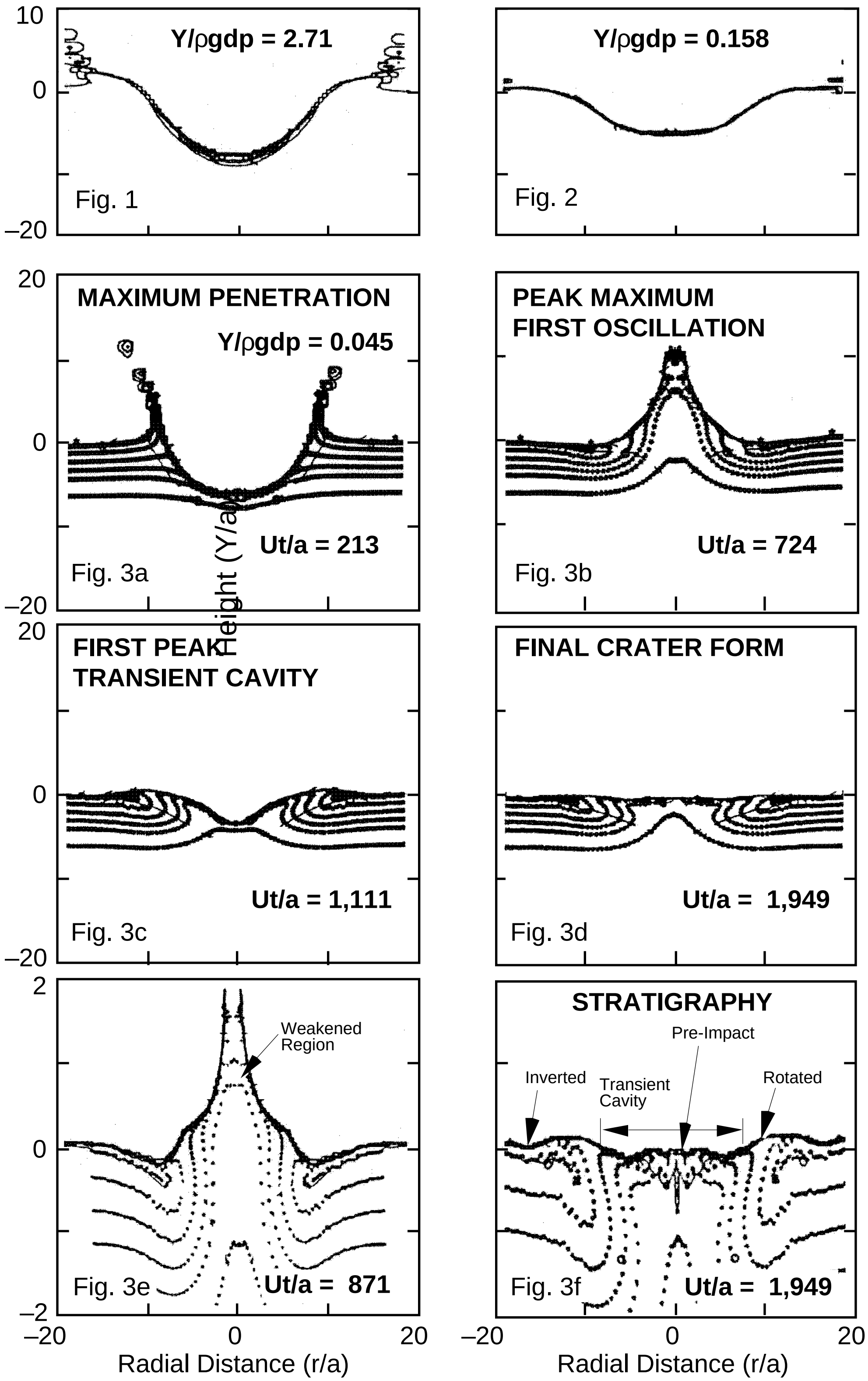

Figure 1. Simple bowl-shaped crater. Figure 2. Incipient flat-floored crater.
Figure 3. Complex crater evolution. Note expanded vertical scale in e and f.